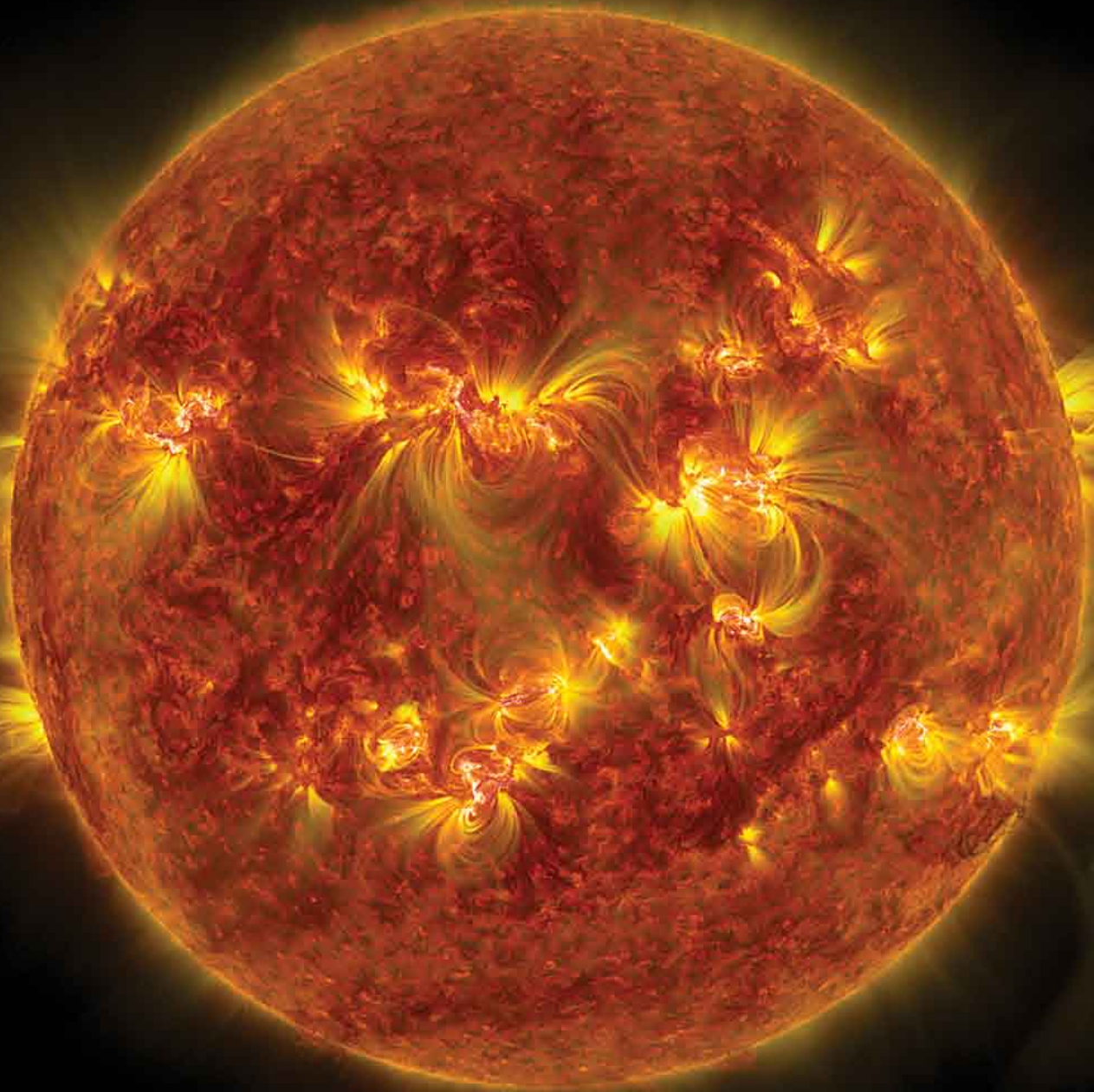


# The Dynamic Sun



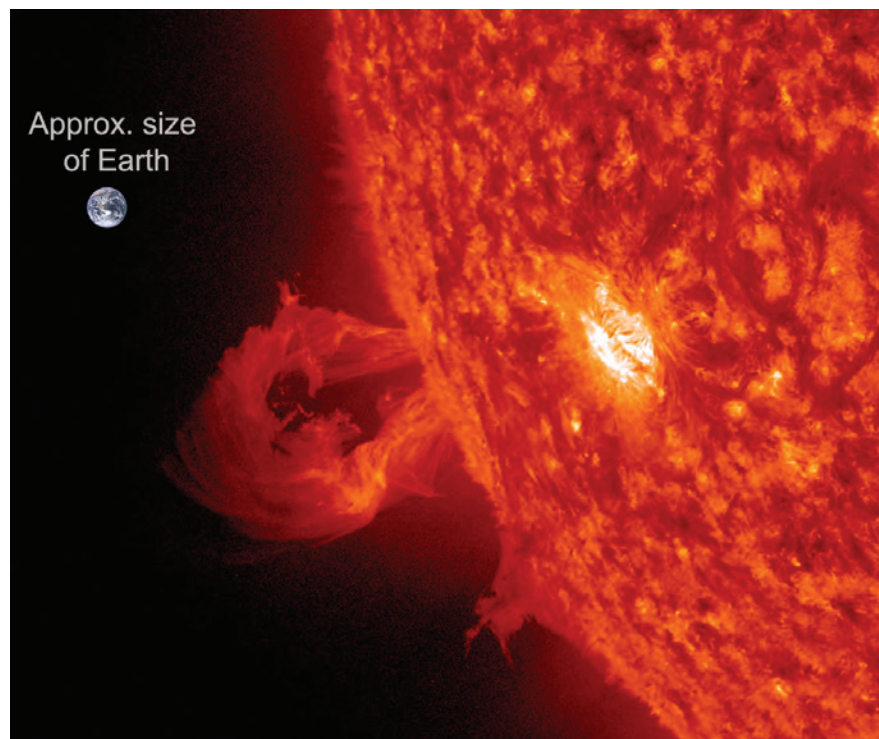
High resolution image of bright active regions and loops of magnetic field lines  
observed in extreme ultraviolet light

# Learn more about the Sun and how it affects us

## Introduction

There is a profound and very direct magnetic relationship between Earth (and other planets in the solar system) and the Sun. This connection has economic and practical aspects. These range from predicting the effect of solar events on communications – about half of which are still carried by vulnerable UHF radio – to how they might prove hazardous to both robotic and human missions. The study of “space weather” is an emerging field with direct impact on everything from cell phone calls to air travel. Each new Helio-physics mission has demonstrated how much there is yet to learn about Earth’s nearest star and its relationship to life.

Scientists have learned a lot about the Sun in the 400 years since sunspots were first discovered. We know that the Sun rotates about every 27 days. At its core a huge thermonuclear reactor fuses hydrogen atoms into helium, two of the most common elements, producing million degree temperatures. Near its surface, the Sun is like a pot of boiling water, with bubbles of hot, electrified gas, actually electrons and protons in a fourth state of matter known as plasma, circulating up from the interior, rising to the surface, and sometimes traveling out into space.



Solar eruption blasted a plume of plasma into space.  
Credit: SDO, NASA

## How Big is It?

The Sun is basically an average star in size and shares many similarities with most stars. The Sun is about 864,000 miles (1.4 million km) across, which means that almost 110 Earths could be placed side by side across it. The next closest star, Alpha Centauri, is over four light years away (the distance that light travels in one year) and twinkles in the night sky like the other stars. Yet, even though the Sun is 93 million miles away from Earth, it appears to be moon-sized because the moon is only 250,000 miles from Earth. This is evident during a solar eclipse.

## Magnetic Connections

The Sun and Earth both have magnetic fields that extend beyond their surfaces. On a much smaller scale, sunspots, which are darker, cooler areas on the Sun, are, in fact, areas of intense mag-

netic forces. These magnetic fields extend from within the Sun to create great arches and loops above the surface. The buildup and interaction of these magnetic loops seems to produce the violent explosion called coronal mass ejections (CMEs). A CME is an eruption of a huge bubble of plasma from the Sun’s outer atmosphere, or corona (the gaseous region above the surface that extends millions of miles into space).

When the Sun blasts a solar storm (made up of a cloud of charged particles) into space, it carries some of the Sun’s magnetic field with it. These CMEs are somewhat like solar hurricanes. They are one of the most important solar events for us on Earth: the eruption of a huge bubble of plasma from the Sun’s outer atmosphere, or corona (the gaseous region above the surface that extends millions of miles into space). Complicated magnetic fields extend from inside the Sun to create great arches and loops above the surface. The interaction of these magnetic features seems to supply the energy needed to produce CMEs.

A CME races through space and can reach us in one to five days. A typical CME can carry more than 10 billion tons of particles into the solar system, a mass equal to that of 100,000 battleships. As it expands in space, it becomes very thin, but it is the magnetic energy that it carries that can upset technology here at Earth.

## About the front image:

This image shows how the Sun appears in a combination of two wavelengths of extreme ultraviolet (UV) light. The bright areas represent active regions, areas of greater intensity of magnetic energy. The bright loops are charged particles tracing magnetic field lines above the active regions. Our eyes cannot see UV light, so the colors used are chosen to represent different temperatures of solar materials.



For more information, see  
[www.nasa.gov/sunearth](http://www.nasa.gov/sunearth)

## Effects on Earth

How do the energy and magnetic fields carried with the plasma in a solar storm impact Earth? Earth has a protective magnetic shield in space called the magnetosphere. It is like having a bar magnet from the North Pole to the South Pole. The energy from a CME does not directly reach the surface of Earth. The cloud is blocked by our own magnetosphere, then slides around to the back side of Earth, where it can inject energy into Earth’s magnetosphere, exciting particles trapped there. Under certain conditions, the particles follow the magnetic field lines down to Earth near the Poles. The visible signs of this activity are beautiful aurora (the Northern and Southern lights), shimmering curtains of colorful glowing lights seen in the night sky.

When we experience a magnetic connection with the Sun, it can affect our technology. Magnetic reconnection is one of the most important drivers of “space weather” events. Eruptive solar flares, coronal mass ejections, and geomagnetic storms all involve the release, through reconnection, of energy stored in magnetic fields. Space weather events can affect modern technological systems such as communications networks, GPS navigation, and electrical power grids.

At times various kinds of technology suffer harmful effects: satellites fail, electric generators get overloaded; and communication and navigation equipment become disrupted. Astronauts working and traveling in space can be exposed to harmful radiation; however, the radiation cannot pass through Earth’s protective magnetosphere and atmosphere to physically affect humans on Earth.

## How NASA Studies the Sun and Space Weather Events

Scientists and engineers at NASA are working hard to find ways to better observe and then predict when these solar storms will occur and how Earth and other planets and bodies in the solar system will respond.

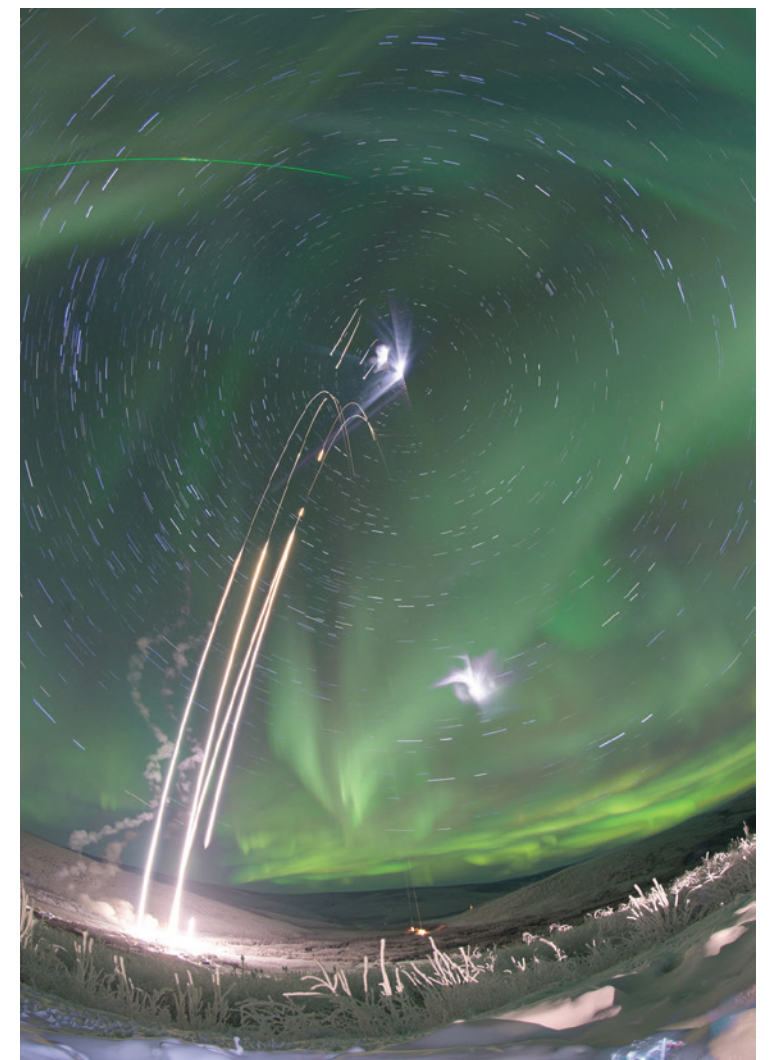
The graphic (right) identifies the current fleet of missions, known as the Heliophysics System Observatory involved in this effort. Some of these spacecraft study the Sun, others study the space between the Sun and Earth and the effects of solar storms on Earth and its magnetosphere, while others also study how the solar wind and solar storms impact interplanetary space and the interstellar boundary at the edge of our solar system. Together they form a cohesive fleet of spacecraft that is advancing our knowledge of the complex physical interactions that generate space weather events.

Several recent and upcoming missions have already and will be making more exciting discoveries. For instance, the Interface Region Imaging Spectrograph (IRIS) has provided scientists with new findings about how the Sun’s corona, is heated far hotter than its surface, what causes the Sun’s constant outflow of particles called the solar wind, and what mechanisms speed-up particles that power solar flares. The Van Allen Probes, which launched in 2012, discovered a third belt in the Van Allen radiation belts (bands of particles that encircle Earth) that can trap the fastest, high-energy electrons. Finally, the Magnetospheric Multiscale Mission (MMS) that launched in March 2015 is currently using Earth’s protective magnetic field, the magnetosphere, as a natural laboratory to directly observe how it interacts with the Sun’s extended magnetic field, which can result in magnetic reconnection events.

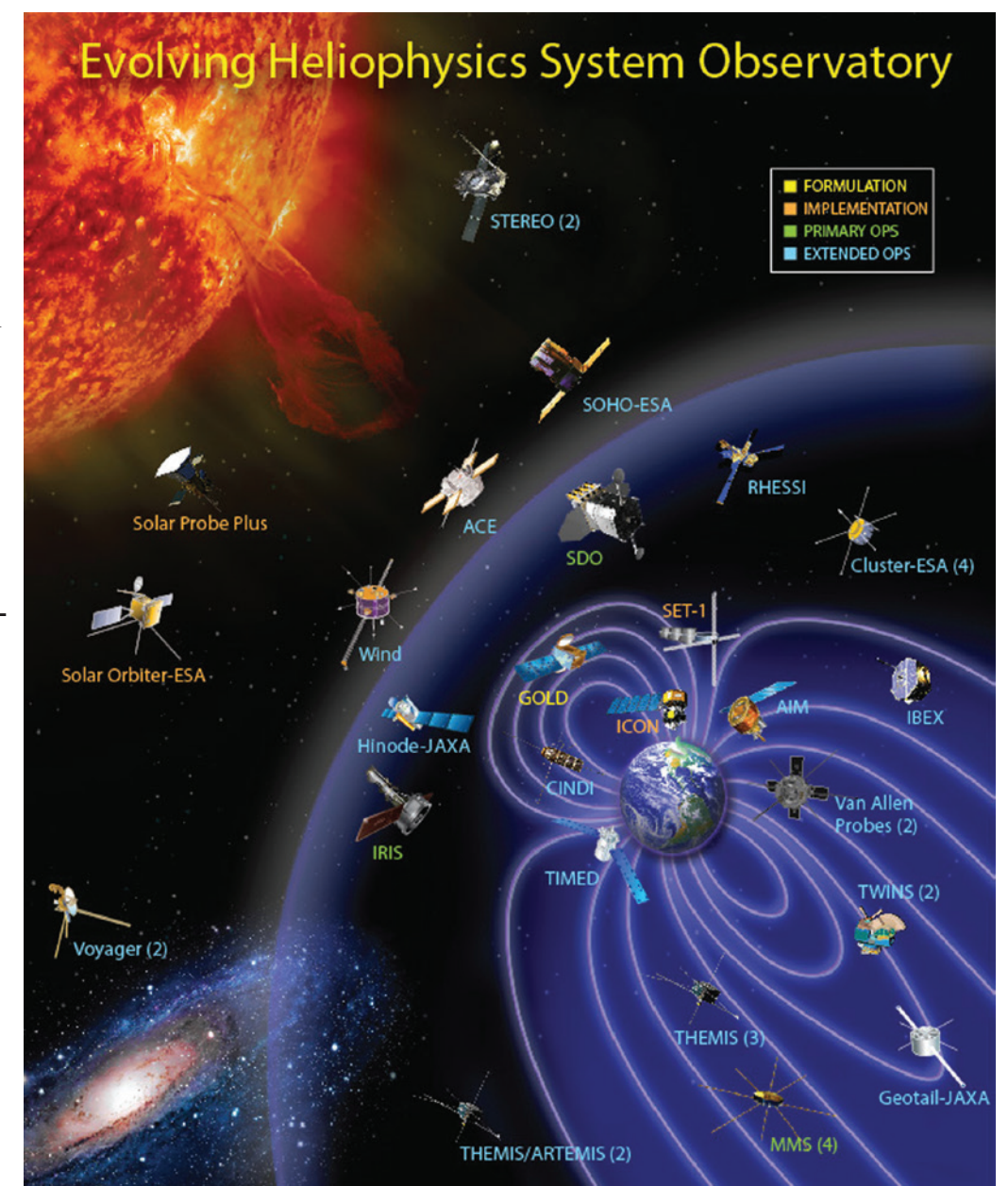
## Solar Dynamics Observatory

The Solar Dynamics Observatory (SDO) launched in 2010 and is one of the largest solar observing spacecraft ever put into orbit. The spacecraft is 4.5 meters high and over 2 meters on each side. It weighed 3000 kg (6620 lb) at launch and its solar panels are 6.5 meters (21.3 ft) wide. They provide the power SDO needs.

SDO tracks solar activity in new ways. Six cameras on SDO take photos of the Sun every three-quarters of a second. Images from two instruments are 10 times sharper than what you see on high-definition TV. These cameras capture images that are best seen on screens that are five feet by five feet. They continue to reveal details of solar activity that scientist have never seen before. In less than five years, one of its instruments had taken over 100 million images of the Sun.



Composite shot of all four rockets for the M-Tex and MIST experiments with aurora in Alaska. Credit: NASA.



Representation of the entire fleet of Heliophysics spacecraft



Artist's representation of the SDO spacecraft watching the Sun all day, every day.